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UNITED STATES PATENT APPLICATION

OF

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FOR

METHOD AND SYSTEM FOR PREVENTING SUN-TRANSIT OUTAGES IN POINT-TO-MULTIPOINT SATELLITE SYSTEMS

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METHOD AND SYSTEM FOR PREVENTING SUN TRANSIT OUTAGES IN POINT-TO-MULTIPOINT SATELLITE SYSTEMS

Related Applications

This application is a continuation-in-part of application Serial Number 08/988,989, filed 12/11/97 ,which is hereby incorporated in its entirety by reference.

Field of the Invention

The present invention relates to geostationary satellite communication antenna. In particular, it relates to small diameter C-band geostationary satellite antenna.

Background of the Invention

Fig. 1 shows a geostationary communication satellite system 100 comprising a plurality of satellites 102_1 to 102_i orbiting the earth 104. Satellite 102_1 is separated from adjacent satellites 102_2 and 102_3 by approximately a 2° arc (the arc is shown by the separation between the dashed lines on each of Figs. 1, 2, 5, and 6, and is typical for geostationary satellites in the United States). Earth 104 has a plurality of earth stations 106_1 to 106_n. Each earth station 106 includes a satellite transmitting and receiving antenna 108. Communication system 100 operates when antenna 108 generates a communication signal 110 that is received by, for example, satellite 102_1, and visa versa.

As communication signal 110 travels from, for example, earth station 106_1 to its intended destination at satellite 102_1 it spreads over an area 112. If communication signal 110 spreads beyond the 2° arc between satellite 102_1 and the adjacent satellites 102_2 and 102_3, then all three satellites 102_1, 102_2, and 102_3 would process communication signal 110 as if it was intended for them. One reason this occurs is that communication signal 110 does not experience significant signal attenuation at the edge of area 112. In order to prevent satellites 102_2 and 102_3 from processing communication signal 110, antenna 108 generates a narrow beam communication signal, instead of a wide beam communication signal.

The most widely used radio frequency bands for satellite communication are the Ku- and C-bands. In both of these bands, a conventional parabolic reflector antenna generates a narrow communication signal to prevent adjacent satellites from processing communication signals not intended for them. The parabolic reflector antenna for the Ku-band may have a relatively small diameter. The small parabolic reflector antenna provides an efficient, cost-effective mechanism for allowing an earth station to communicate with an individual satellite. Unfortunately, Ku-band radio signals attenuate in atmospheric conditions consistent with periods of moderate-to-heavy precipitation, i.e., rain, sleet, or snow. In most cases, providing facilities with sufficient power to compensate for severe signal attenuation is uneconomical. As a result, satellite communications systems operating in the Ku-band experience periodic system outages that are unacceptable for time critical applications.

To avoid periodic system outages due to atmospheric conditions, earth stations typically transmit and receive data using C-band radio frequencies. These frequencies are much less susceptible to attenuation due to precipitation. Therefore, C-band transmitters can economically provide sufficient signal margin to overcome any signal attenuation due to atmospheric conditions. Unfortunately, to generate narrow communication signal beams, C-band parabolic antennas need to be larger than Ku-band antennas. In fact, the minimum C-band parabolic antenna diameter that prevents communication signal 110 from interfering with satellites 102_2 or 102_3 (*See* Fig. 1) is approximately 3.7 meters. For many applications, however, the installation of a 3.7 meter diameter antenna is too unwieldy, aesthetically unseemly, and/or not structurally prudent. Therefore, it would be desirable to use smaller diameter parabolic reflective antenna to transmit C-band radio frequencies while avoiding unnecessary interference with adjacent satellites.

Further, during short periods of each day for several days immediately before and after the vernal and autumnal equinoxes, the sun transits behind geostationary satellites as seen from an earth station's receiving antenna (i.e.,

from the perspective of the earth station, the sun passes behind the geostationary satellite). The sun emits a great deal of energy in the form of electromagnetic radiation in the bandwidth occupied by radio wave communications. Therefore, when the sun is located within the beamwidth of the receiving antenna, its energy causes interference in the form of radio frequency noise. This noise causes a decrease in the signal-to-noise ratio of the earth station's receiver, and can render the earth station inoperative until the sun completes its transit of the antenna's beamwidth.

Because the relative movement of the earth with respect to the sun is known to a high degree of precision, satellite communication system operators are forewarned of the time when the sun will transit the beamwidth of a receiving antenna. Knowledge of a pending problem, however, is only useful if the system operators can keep the system operational during these periods.

For conventional satellite systems, each individual receive antenna might be effected by the sun's positioning during this period. Some conventional systems use costly terrestrial communications facilities to provide continuing operations as the sun transits behind a satellite with respect to its earth station's receiving antenna. Other systems remain off-the-air for the duration of these periods. The inherent inconvenience of this option, however, renders it particularly unattractive. Finally, some conventional satellite systems continue operation by switching each earth station's antenna to a secondary satellite during the period that the sun is within the beamwidth of the antenna. This process requires manual intervention and/or complex automated mechanical mechanisms to perform the daily repositioning of the antenna during its sun transit outage. The cost of the daily repositioning of each antenna so effected renders this option uneconomical.

Therefore, a need exists for a satellite communication system to efficiently provide communication during sun transit outages.

Summary of the Invention

Systems and methods consistent with the present invention address

this need by providing a mechanism for repositioning an earth station's antenna during a sun transit outage. Alternatively systems and methods consistent with the present invention provide a second antenna at the earth station directed toward a second satellite.

In accordance with the purpose of the invention, as embodied and broadly described herein, a point-to-multipoint satellite communication system, comprises a first satellite antenna for generating a wide beam communication signal to illuminate a plurality of satellite, means for generating a return communication signal from each of the plurality of satellites, a second satellite antenna for receiving the return communication signal from only one of the plurality of satellites, and a satellite antenna repositioning system for repositioning said second antenna when the sun transits within the beamwidth of said second antenna.

Both the foregoing general description and the following detailed description are exemplary and explanatory, and are intended to provide further explanation of the invention as claimed.

Brief Description of the Drawings

The accompanying drawings, which are incorporated in and constitute a part of this specification, illustrate preferred embodiments of the invention and, together with the description, explain the goals and principles of the invention. In the drawings,

Fig. 1 is an illustration of a geostationary satellite communication system;

Fig. 2 is an illustration of a geostationary satellite communication system consistent with the present invention;

Fig. 3 is a flow chart illustrating the reception operation of the communication system of Fig. 2;

Fig. 4 is a flow chart illustrating the transmission operation of the communication system of Fig. 2;

Fig. 5 is an illustration of a second geostationary satellite communication system consistent with the present invention;

Fig. 6 is an illustration of a third geostationary satellite communication

system consistent with the present invention;

Fig. 7 is an illustration of a fourth geostationary satellite communication system consistent with the present invention; and

Fig. 8 is an illustration of a fifth geostationary satellite communication system consistent with the present invention.

Description of the Preferred Embodiment

The following detailed description of the invention refers to the accompanying drawings. The same reference numbers in different drawings identify the same or similar elements. Also, the following detailed description does not limit the invention. Instead, the scope of the invention is defined by the appended claims.

Systems and methods consistent with the present invention provide efficient and continuous communications during sun transit outages by providing a secondary channel for communications to continue during the outages.

Communication systems consistent with the present invention comprise a "hub and spoke" configuration. In this configuration, a central earth station acts as the hub and a plurality of earth stations act as the spokes. Communication from the central earth station to any one of the plurality of earth stations is direct in that it involves a single transmission to the satellite and a single transmission from the satellite. Communication between spokes, however, is not direct. A transmitting earth station communicates with the central earth station, which retransmits the signal to a receiving earth station. In this case, there are two transmissions to a satellite and two transmissions from a satellite.

Fig. 2 is a diagram of satellite communication system 200 that uses a relatively small diameter C-band antenna (also called a very small aperture terminal (VSAT) antenna) for the transmission and reception of communication signals. System 200 includes a plurality of satellites 202_1 to 202_i, a central earth station 204, and a plurality of earth stations 206_1 to 206_n. Central earth station 204 transmits to the plurality of satellites 202 via a

communication signal 208. Each of the earth stations 206 transmits to the plurality of satellites 202 via a communication signal 210. Each of the satellites 202 communicates with central earth station 204 and the plurality of earth stations 206 with a return communication signal (not shown).

Central earth station 204 includes a relatively large C-band antenna 214 having a relatively narrow beamwidth. Conversely, each of the plurality of earth stations 206 includes a relatively small C-band antenna 216 having a relatively wide beamwidth.

Fig. 3 is a flow chart 300 of a return communication from one of the satellites 202 to antenna 216. First, central earth station 204 aligns its narrow beam antenna 214 to illuminate a single satellite 202, for example satellite 202_1 (step 302). Next, antenna 214 generates a narrow communication signal 208 (step 304), which is received solely by satellite 202_1 (step 306). Based on communication signal 208, satellite 202_1 broadcasts a return communication signal (step 308). Antenna 216 receives the return communication signal (step 310).

Fig. 4 is a flow chart 400 illustrating the transmission of a communication signal 210 from antenna 216 to the plurality of satellites 202. First, one of the earth stations 206 aligns its antenna 216 to illuminate satellite 202_1 (step 402). Next, antenna 216 generates a relatively wide communication signal 210 (step 404), which is received by satellite 202_1, along with the other satellites within the gain pattern of signal 210, such as satellites 202_2 and 202_3 (step 406). In response to communication signal 210, each of the satellites broadcasts return communication signals (step 408). Due to its narrow beamwidth, however, antenna 214 receives the return communication signal from the single satellite at which it is pointed (i.e., satellite 202_1).

During transmission from antenna 216, both satellites 202_2 and 202_3 receive communication signal 210. Due to its wide beamwidth, antenna 216 receives return communication signals from all three satellites 202_1, 202_2 and 202_3, though it is pointed only towards satellite 202_1. In the above example, when antenna 216 is aligned with satellite 202_1, it can receive return

communication signals from each of satellites 202_1, 202_2 , and 202_3.

If an antenna outside communication system 200 mistakenly illuminates a satellite within system 200, the received signal is seen by system 200 as an interference signal ("interference signal" is defined as a communication signal generated by an antenna outside a communication system that operates on the same frequency band). The illuminated satellite retransmits the signal to antenna 216, because the satellite does not distinguish the source of the signal.

Similarly, when antenna 216 illuminates satellites 202_1, 202_2, and 202_3 with communication signal 210, each of satellites 202_1, 202_2, and 202_3 transmits a return communication signal. An antenna outside of communication system 200 that is aligned with one of the satellites would receive the return communication signal. In order to avoid these types of interference, it is preferable to obtain exclusive use, on satellites 202_1, 202_2, and 202_3, of the particular frequencies that communication system 200 will use.

Although the disclosure is directed to a communication system with a central and two adjacent satellites, virtually any number of satellite configurations are possible. For example, Fig. 5 shows a communication system 500 that uses two satellites 502_1, and 502_2. Fig. 6 shows a communication system 600 that uses five satellites 602_1, 602_2 , 602_3, 602_4, and 602_5 . Communication systems 500 and 600 both operate in a manner similar to system 200 described above.

As noted above, it is preferable to exclude other satellite communication systems from using the bandwidth employed by communication system 200. However, it is not possible to control the frequencies emitted by the sun as it transits behind satellites 202 with respect to the earth. Large C-band antennas, such as antenna 214, are particularly sensitive to the noise signal emitted by the sun. This sensitivity is caused by the amplification of the sun signal received within the narrow beamwidth of the large antenna. Smaller VSAT antennas 216 do not receive as large a noise signal due to the lower level of amplification of the signal received

within their wide beamwidth.

Sun transit outage is of particular concern to operators of large point-to-multipoint (hub and spoke) satellite systems as described herein. In these hub and spoke type networks, such as system 200, all communications necessarily pass through hub antenna 214 of central earth station 204. During the transit of the sun through the beamwidth of antenna 214, the entire system becomes inoperative.

Fig. 7 is a diagram of a satellite communication system 700 that includes a satellite antenna repositioning system 720 to overcome the problem of sun transit outages. Because relatively small C-band antenna 216, or VSAT antenna, has a relatively wide beamwidth, antenna 216 communicates with several satellites, including, for example, satellites 202_1, 202_2, and 202_3. Upon receiving a signal 210 from antenna 216, each of satellites 202_1, 202_2, and 202_3 broadcasts a return communication signal. During the period that the sun passes through the beamwidth of antenna 214 (i.e., behind satellite 202_1), satellite antenna repositioning system 720 repositions antenna 214 to point to one of the proximate secondary satellites 202_2 or 202_3. As noted above, due to the relatively wide beamwidth of antennas 216, they remain in operation while the sun transits their beamwidths. Following the repositioning, therefore, antenna 214 can both transmit signals to and receive signals from antennas 216.

Fig. 8 is a diagram of a satellite communication system 800, which includes a second relatively large C-band antenna 814 installed at the central earth station 204. Station 204 directs antenna 214 at satellite 202_1, and antenna 814 at one of the proximate secondary satellites 202_2 or 202_3. During the period of transit of the sun behind satellite 202_1 with respect to antenna 214, central earth station 204 discontinues use of antenna 214 and switches to antenna 814. The operation of switching from one antenna to another is performed by an antenna switch selector (not shown). Once again, because of the relatively wide beamwidth of antenna 216, the sun does not have as large an effect on the signal-to-noise ratio of the received signal as the sun transits within the beamwidths of antennas 216. The relatively wide

beamwidths of antennas 216 also results in the illumination of satellites 202_1, and proximate secondary satellites 202_2, and 202_3. The communication link between antenna 216 and central earth station 204 is thereby maintained during the sun transit of the beamwidth of satellite 202_1 by receiving the signal from a proximate secondary satellite using antenna 814.

It will be apparent to those skilled in the art that various modifications and variations can be made in the methods and apparatus consistent with the present invention without departing from the scope or spirit of the invention. Other modification will be apparent to those skilled in the art from consideration of the specification and practice of the invention disclosed herein. The specification and examples should be considered as exemplary only, with the true scope and spirit of the invention being indicated by the following claims.